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TUNING ALGORITHM FOR TEVATRON INJECTION

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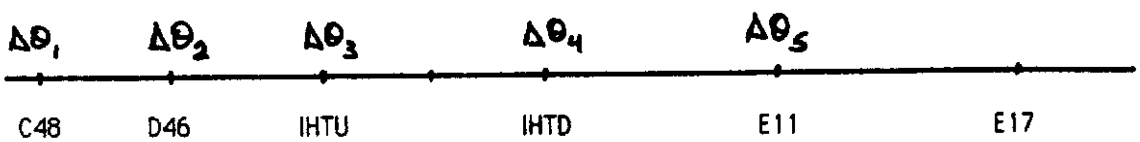
An algorithm is developed in this report which will improve the process of transfering protons from the Main Ring (MR), through the beam transfer line system, to the Tevatron. The operator is instructed to choose a specified pair of dipole magnets within the system, and to adjust the angle deviations of the beam at their locations according to calculated values. These angle deviations may have different polarities and therefore would require adjustments in opposite directions.

There are five dipole magnets in this beam transfer system, which contribute to the large horizontal, beam excursions recorded in the Tevatron. Each dipole can be considered a source of path deviation or angle deviation which causes error in beam position and beam slope at a designated place in the Tevatron, i.e. E17. The five dipoles are 1). the C48 kicker magnet in the MR, 2). the D46 bump magnet in the MR, 3). the upstream trim magnet (IHTU) in the transfer line, 4). the downstream trim magnet (IHTD) in the transfer line, and 5). the E11 bump magnet in the Tevatron. See diagram below



The objective of this report is threefold. First, to determine which pair of magnets, out of a combination of ten pairs, will produce the maximum change in beam position error at E17(Tevatron) without changing the error in beam slope at the same position. Secondly, to determine which pair of magnets will produce the maximum change in beam slope error at E17(Tevatron) without changing the error in beam position at the same location. Finally, to develop a program which will supply accelerator operators with the calculated set of angle data they require for tuning.

The concept behind the algorithm is that there are ten combinations of angle deviations which effect the horizontal motion of the beam at E17.

The angle deviations and beam characteristics at each magnet member of the pair must be properly transported to E17 using the appropriate beta functions and transport matrices. Therefore for the ten angle deviation pairs listed below, the transport equations are:

$\Delta\theta_1, \Delta\theta_2$ $\quad$ $\Delta\theta_2, \Delta\theta_3$ $\quad$ $\Delta\theta_3, \Delta\theta_4$ $\quad$ $\Delta\theta_4, \Delta\theta_5$
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$\Delta\theta_1, \Delta\theta_4$ $\quad$ $\Delta\theta_2, \Delta\theta_5$
$\Delta\theta_1, \Delta\theta_5$

and

(1)	$13.0977D\theta_1 - 17.0457D\theta_2$	=	Dx (at E17)
	$0.7620D\theta_1 + 1.2986D\theta_2$	=	Dx` (at E17)
(2)	$13.0954D\theta_1 - 69.3957D\theta_3$	=	Dx (at E17)
	$0.7593D\theta_1 + 0.9611D\theta_3$	=	Dx` (at E17)
(3)	$13.1018D\theta_1 - 61.7406D\theta_4$	=	Dx (at E17)
	$0.7647D\theta_1 + 0.5099D\theta_4$	=	Dx` (at E17)
(4)	$13.0964D\theta_1 - 25.9050D\theta_5$	=	Dx (at E17)
	$0.7604D\theta_1 - 0.2700D\theta_5$	=	Dx` (at E17)
(5)	$-17.0426D\theta_2 - 69.3957D\theta_3$	=	Dx (at E17)
	$1.2963D\theta_2 + 0.9611D\theta_3$	=	Dx` (at E17)
(6)	$-17.0452D\theta_2 - 61.7406D\theta_4$	=	Dx (at E17)
	$1.3030D\theta_2 + 0.5099D\theta_4$	=	Dx` (at E17)
(7)	$-17.0487D\theta_2 - 25.9050D\theta_5$	=	Dx (at E17)
	$-1.2970D\theta_2 - 0.2700D\theta_5$	=	Dx` (at E17)
(8)	$-69.3906D\theta_3 - 61.7406D\theta_4$	=	Dx (at E17)
	$0.9624D\theta_3 + 0.5099D\theta_4$	=	Dx` (at E17)
(9)	$-69.3983D\theta_3 - 25.7771D\theta_5$	=	Dx (at E17)
	$0.9583D\theta_3 - 0.2700D\theta_5$	=	Dx` (at E17)
(10)	$-61.7395D\theta_4 - 25.9050D\theta_5$	=	Dx (at E17)
	$0.5081D\theta_4 - 0.2700D\theta_5$	=	Dx` (at E17)

If we require tuning the beam position error independant of the beam slope error, then the constraint equations become:

$$AD\theta_i + BD\theta_j = Dx\,(E17)$$
$$CD\theta_i + GD\theta_j = 0.$$

or,

$$D\theta_i = \frac{G(Dx)}{AG - BC}, \quad D\theta_j = \frac{-C(Dx)}{AG - BC}$$

If we require tuning the beam slope error independant of the beam position error, then the constraint equations become, where A,B,C,G are given by the coefficients of the transport equations:

$$AD\theta_i + BD\theta_j = 0.$$
$$CD\theta_i + GD\theta_j = Dx' \quad (E17)$$

or,

$$D\theta_i = \frac{-B(DX')}{AG - BC}, \quad D\theta_j = \frac{A(DX')}{AG - BC}$$

Figures 1 and 2 illustrate the distribution of beam slope and position errors as a function of the sum of two angle deviations. In each figure the C48, E11(Tevatron) magnet combination has a maximum effect on the horizontal beam orientation at E17(Tevatron). For example, if Dx = 1.790 mm and Dx' = 0.070 mrad at E17(Tevatron) the maximum change in slope, without any change to the position, becomes:

$$D\theta_1 + D\theta_5 = 1.6028(\ 0.070 \text{ mrad}\ ) + 0.8103(\ 0.070 \text{ mrad}\ )$$
$$= 0.1689 \text{ mrad}$$

The maximum change in position at E17, without any change to slope, becomes:

$$D\theta_1 + D\theta_5 = -0.0167(\ 1.790 \text{ mm}\ ) - 0.0470(\ 1.790 \text{ mm}\ )$$
$$= -0.1140 \text{ mm}$$

Figure 1. ERRORS IN BEAM SLOPE AT E17(TEV) versus PAIRS OF BEAM-ANGLE-ERRORS

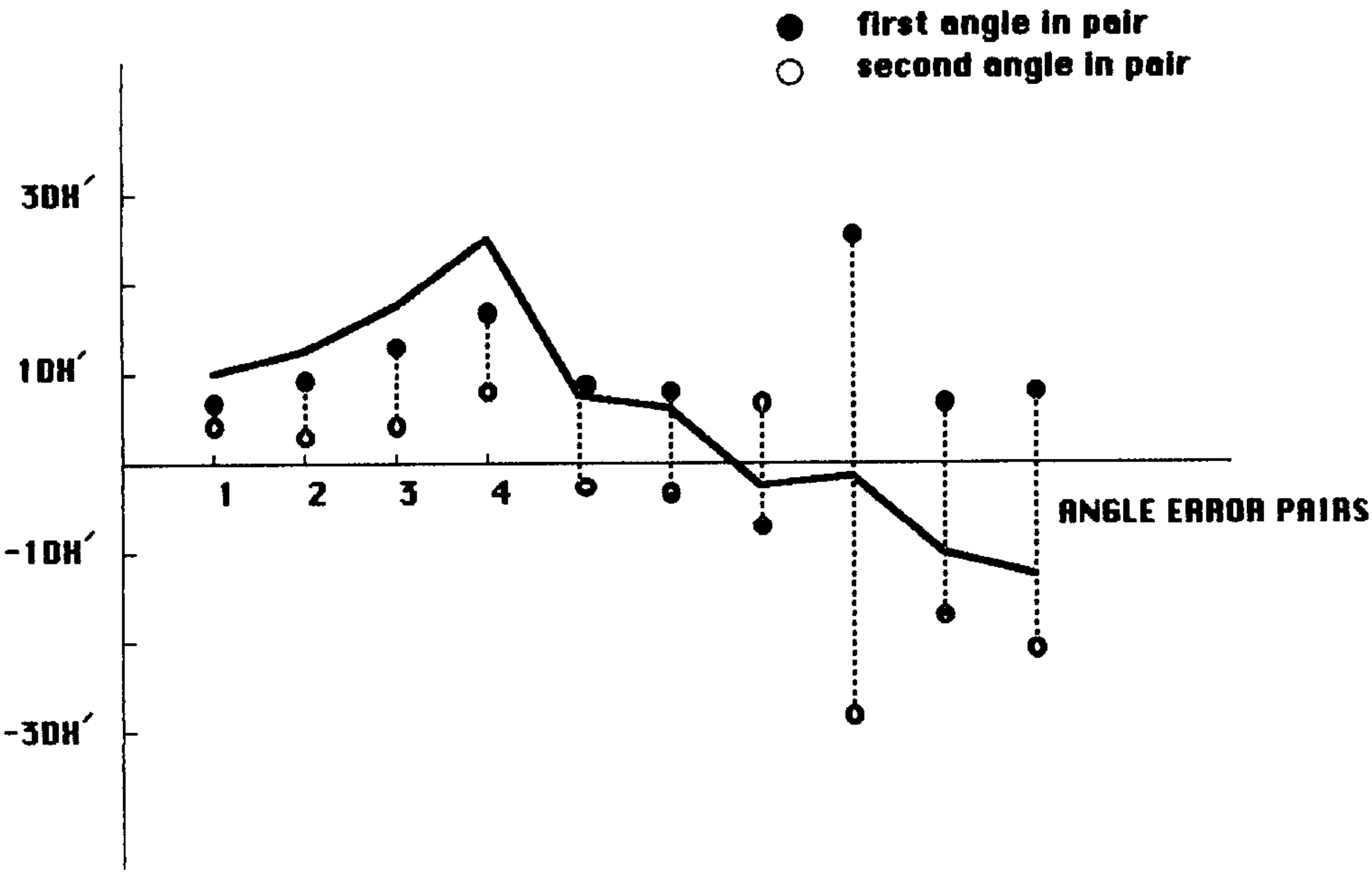

Figure 2. ERRORS IN BEAM POSITION AT E17 (TEV) versus PAIRS OF BEAM-ANGLE-ERRORS